

**TITLE**

**FLAT PANEL DISPLAY DEVICE HAVING ANODE SUBSTRATE  
INCLUDING CONDUCTIVE LAYERS MADE OF  
CARBON-BASED MATERIAL**

**CLAIM OF PRIORITY**

**[0001]** This application makes reference to, incorporates the same herein, and claims all benefits accruing under 35 U.S.C. § 119 from an application for *FLAT PANEL DISPLAY DEVICE HAVING ANODE PLATE FORMED CARBON-BASED CONDUCTIVE LAYER* earlier filed in the Korean Intellectual Property Office on 17 January 2003 and there duly assigned Serial No. 2003-3278.

**BACKGROUND OF THE INVENTION**

**Technical Field**

**[0002]** The present invention relates to a flat panel display device, and more particularly, to a field emission display.

**Related Art**

**[0003]** A flat panel display device typically includes two substrates, in which a cathode assembly is provided on one of the substrates and an anode assembly is provided on the other of the substrates. Electrons emitted from the cathode assembly strike elements of the anode assembly to illuminate the same, thereby realizing the display of predetermined images.

1   **[0004]** A field emission display (FED) is a type of flat panel display device. The following two  
2   references are exemplars of features related to field emission devices. The U.S. Patent Number  
3   5,593,562 issued to Vickers on 14 January 1997 and entitled *METHOD FOR IMPROVING FLAT*  
4   *PANEL DISPLAY ANODE PLATE PHOSPHOR EFFICIENCY* discloses a method of fabricating  
5   an anode plate for use in a field emission device. The U.S. Patent Number 5,830,527 issued to  
6   Vickers on 3 November 1998 and entitled *FLAT PANEL DISPLAY ANODE STRUCTURE AND*  
7   *METHOD OF MAKING* discloses a structure and method of fabricating an anode plate for use in  
8   a field emission device. Such field emission displays have conductive material formed between  
9   phosphors on an anode electrode. We have discovered that the removal process is difficult to  
10   control with this method of depositing conductive material on the phosphors and then removing  
11   predetermined areas of the conductive material.

## 12                                   SUMMARY OF THE INVENTION

13   **[0005]** It is therefore, an object of the present invention to provide an improved process of  
14   making, and an improved field emission display.

15   **[0006]** It is another object to provide a field emission display made by depositing conductive  
16   material onto phosphor and removing predetermined areas of the phosphor, in a process that is  
17   amenable to reliable control.

18   **[0007]** These and other objects may be attained according to the principles of the present  
19   invention with a process and a flat panel display device having an anode substrate in which good  
20   electric conduction is realized between phosphor particles forming phosphor layers. The present

1 invention contemplates a flat panel display device, in which conductive layers for removing  
2 electric charges accumulated on surfaces of phosphors are easily formed.

3 **[0008]** In one embodiment, the present invention provides a flat panel display device including  
4 a first substrate; an electron emission assembly formed on the first substrate; a second substrate  
5 provided at a predetermined distance from the first substrate and forming a vacuum assembly with  
6 the first substrate; and an illumination assembly formed on the second substrate, the illumination  
7 assembly being illuminated by electrons emitted from the electron emission assembly. The  
8 illumination assembly includes at least one anode electrode formed on a surface of the second  
9 substrate facing the first substrate, phosphor layers formed in a predetermined pattern on the at  
10 least one anode electrode, and conductive layers formed of a carbon-based material on the  
11 phosphor layers.

12 **[0009]** Preferably, the conductive layers are made of carbon nanotubes and are formed using  
13 electrophoresis.

14 **[0010]** The at least one anode electrode may be formed in a predetermined anode electrode  
15 pattern of a plurality of anode electrodes formed at a predetermined distance on the second  
16 substrate to form a striped pattern. Also, black matrix layers may be formed between the anode  
17 electrodes, in a state of not making electrical contact with the anode electrodes, or formed between  
18 the anode electrodes in a state of making electrical contact with the anode electrodes. The black

1 matrix layers have electrical conductivity and the conductive layers are in electrical contact with  
2 the black matrix layers. That is, the black matrix layers conduct electricity and the conductive  
3 layers electrically contact the black matrix layers.

4 **[0011]** The at least one anode electrode may be formed as a single unit over all of the surface  
5 of the second substrate facing the first substrate. The phosphor layers and black matrix layers are  
6 formed on the anode electrode, in such a way as to be electrically connected or as to lack electrical  
7 connection to the anode electrode as described in the foregoing paragraphs.

8 **[0012]** The electron emission assembly includes cathode electrodes formed on a surface of the  
9 first substrate facing the second substrate; at least one gate electrode formed on the surface of the  
10 first substrate facing the second substrate; an insulation layer formed between the cathode  
11 electrodes and the at the least one gate electrode; and electron emission sources mounted within  
12 holes formed in the cathode electrodes and the gate electrodes such that the electron emission  
13 sources are formed on the cathode electrodes.

14 **[0013]** The electron emission assembly can include cathode electrodes formed on a surface of  
15 the first substrate facing the second substrate; at least one gate electrode formed on the surface of  
16 the first substrate facing the second substrate; an insulation layer formed between the cathode  
17 electrodes and the at the least one gate electrode; and electron emission sources mounted on the  
18 cathode electrodes.

1     **[0014]**     The electron emission sources are made of a carbon-based material such as carbon  
2     nanotubes, fullerenes such as C<sub>60</sub>, diamond-like carbon (DLC), and graphite, or a mixture of these  
3     carbon-based materials. The electron emission sources are made into a flat shape. In another  
4     aspect, the electron emission sources are made of a metal material such as molybdenum and  
5     formed into a circular shape.

6     **[0015]**     The present invention provides a method for manufacturing a flat panel display device  
7     by forming anode electrodes on a substrate; forming phosphor layers on the anode electrodes;  
8     preparing a solution in which carbon-based material is dispersed; immersing the substrate on  
9     which the phosphor layers are to be formed into the solution and adhering the carbon-based  
10    material on a surface of the phosphor layers by electrophoresis; and cleaning and then drying the  
11    substrate and elements formed thereon.

12    **[0016]**     In accordance with the principles of the present invention, as embodied and broadly  
13    described, the present invention provides a flat panel display device that may be constructed with  
14    a first substrate; an electron emission assembly being formed on the first substrate; a second  
15    substrate provided at a predetermined distance from the first substrate, said first and second  
16    substrates forming a vacuum assembly; and an illumination assembly formed on the second  
17    substrate, with the illumination assembly being illuminated by electrons emitted from the electron  
18    emission assembly. The illumination assembly may be constructed with at least one anode  
19    electrode being formed on a first surface of the second substrate to face the first substrate, and with

1 the first surface of the second substrate facing the first substrate; a plurality of phosphor layers  
2 formed in a predetermined pattern on at least one anode electrode; and a plurality of conductive  
3 layers formed on the phosphor layers, with the plurality of conductive layers being formed of a  
4 carbon-based material.

5 **[0017]** In accordance with the principles of the present invention, as embodied and broadly  
6 described, the present invention provides a method for manufacturing a flat panel display device  
7 that may be practiced by forming anode electrodes on a substrate, forming phosphor layers on the  
8 anode electrodes, immersing the substrate in a solution including dispersed carbon-based material,  
9 adhering the carbon-based material onto a surface of the phosphor layers by electrophoresis, and  
10 cleaning and then drying the substrate.

11 **[0018]** The present invention is more specifically described in the following paragraphs by  
12 reference to the drawings attached only by way of example. Other advantages and features will  
13 become apparent from the following description and from the claims.

#### 14 BRIEF DESCRIPTION OF THE DRAWINGS

15 **[0019]** In the accompanying drawings, which are incorporated in and constitute a part of this  
16 specification, embodiments of the invention are illustrated, which, together with a general  
17 description of the invention given above, and the detailed description given below, serve to  
18 exemplify the principles of this invention.

1     **[0020]** FIG. 1 is a partial cross-sectional view of a flat panel display device constructed as a first  
2     embodiment of the present invention;

3     **[0021]** FIG. 2 is a partial cross-sectional view of an anode substrate of the flat panel display of  
4     FIG. 1, constructed in accordance with the principles of the present invention;

5     **[0022]** FIG. 3 is a schematic view used to describe a method for manufacturing a conductive  
6     layer according to the principles of the present invention;

7     **[0023]** FIG. 4 is a two-coordinate graph used to compare characteristics of a first display device,  
8     corresponding to the first embodiment of the present invention, with characteristics of a second  
9     display device serving as a comparative example;

10    **[0024]** FIG. 5 is a partial cross-sectional view of an anode substrate constructed as a  
11    modification of the examples of the first embodiment of the present invention;

12    **[0025]** FIG. 6 is a partial cross-sectional view of an anode substrate modified from the examples  
13    of the first embodiment of the present invention;

14    **[0026]** FIG. 7 is a partial cross-sectional view of a flat panel display constructed as a second  
15    embodiment of the present invention; and

16    **[0027]** FIG. 8 is a partial orthogonal view of a flat panel display constructed as a third  
17    embodiment of the present invention.

## 18                   **DETAILED DESCRIPTION OF THE EMBODIMENTS**

19    **[0028]** While the present invention will be described more fully hereinafter with reference to  
20    the accompanying drawings, in which details of the present invention are shown, it is to be

1 understood at the outset of the description which follows that persons of skill in the appropriate  
2 arts may modify the invention here described while still achieving the favorable results of this  
3 invention. Accordingly, the description of the best mode contemplated of carrying out the  
4 invention, which follows, is to be understood as being a broad, teaching disclosure directed to  
5 persons of skill in the appropriate arts, and not as limiting upon the present invention.

6 **[0029]** Illustrative embodiments of the best mode of carrying out the invention are described  
7 below. In the interest of clarity, not all features of an actual implementation are described. In the  
8 following description, well-known functions, constructions, and configurations are not described  
9 in detail since they could obscure the invention with unnecessary detail. It will be appreciated that  
10 in the development of any actual embodiment numerous implementation-specific decisions must  
11 be made to achieve the developers' specific goals, such as compliance with system-related and  
12 business-related constraints, which will vary from one implementation to another. Moreover, it  
13 will be appreciated that such a development effort might be complex and time-consuming, but  
14 would nevertheless be a routine undertaking for those of ordinary skill having the benefit of this  
15 disclosure.

16 **[0030]** In the drawings, the thickness of layers and regions are exaggerated for clarity. It  
17 will also be understood that when a layer is referred to as being “on” another layer or substrate,  
18 it can be directly on the other layer or substrate or alternatively, intermediate or intervening layers  
19 may also be present. Moreover, each embodiment described and illustrated herein includes its



1 complementary conductivity type embodiment as well. A field emission display (FED) is a type  
2 of flat panel display device. In the field emission display, cold cathode sources, which are the  
3 sources of electrons, are provided on a cathode substrate. Also, formed on an anode substrate are  
4 phosphor layers, which are struck by the emitted electrons to be excited by the same and realize  
5 predetermined colors. That is, the phosphor layers are illuminated by the landing of the electrons  
6 thereon to realize predetermined images.

7 **[0031]** The phosphor layers illuminated in this manner are formed of phosphors, which are  
8 realized through non-conductive particles. As a result, during operation of the field emission  
9 display, there is a high probability that electric charges will accumulate on surfaces of the  
10 phosphors when they are illuminated. These electric charges interfere with the landing of electron  
11 beams formed by the emitted electrons, on their intended phosphor layers. That is, the electric  
12 charges accumulated on the surfaces of phosphors deleteriously affect the paths of travel of the  
13 electron beams so that the electron beams do not land on their intended phosphor layers. This  
14 makes it difficult to attain the desired brightness characteristics of the field emission display.

15 **[0032]** The accumulated electric charge may also abruptly discharge and cause arcing when the  
16 display is driven. In order to obtain a desired brightness in display devices including a field  
17 emission display, a predetermined amount of electrons are needed. With the accumulation of the  
18 electric charges on the phosphors as described above however, it is necessary to irradiate electron  
19 beams having an electric charge amount that is as great as that accumulated on the phosphors.

1 This makes it necessary to increase the required voltage applied to the display for electron beam  
2 emission, which undesirably increases power consumption.

3 **[0033]** Some field emission displays may attempt to correct some of these problems by coating  
4 the surfaces of each of the phosphor layers with a conductive layer. The conductive layers increase  
5 the illumination efficiency of the phosphors by interaction with the electron beams so that  
6 brightness is improved. Such field emission displays have conductive material formed between  
7 phosphors on an anode electrode. An example of the conductive material is aluminum metal film.  
8 The conductive material removes electric charges that may form on the surfaces of the phosphors.  
9 After providing phosphors on the anode electrode and the conductive material on the phosphors,  
10 portions of the phosphors, that is, non-active surface layers formed on particle surfaces of the  
11 phosphors, and the conductive material deposited on the phosphors are removed by a method such  
12 as sputtering, etching, or ion milling.

13 **[0034]** In such a method of depositing conductive material on the phosphors and removing  
14 predetermined areas of the conductive material however, the removal process is difficult to  
15 control. As a result, it is hard to perform formation so that adequate conductive material remains  
16 in a suitable manner between the phosphors. This ultimately results in complications in the  
17 placement of conductive material suggested by the foregoing patents in order to satisfactorily  
18 electrically interconnect the phosphors as to reliably remove the electric charge accumulated on  
19 the surfaces of the phosphors.

1     **[0035]**     Moreover, when the conductive material is deposited on the phosphors using some of  
2     the methods taught by those patents, it is necessary to use expensive manufacturing equipment.  
3     This increases overall production costs.

4     **[0036]**     Furthermore, with the coating of the surfaces of the phosphors with metal films in an  
5     attempt to improve the brightness of the device, when the completed device is driven at a low  
6     voltage applied to the anode electrode, it is difficult for the electrons emitted from the electron  
7     emission sources to pass through the metal films in order to illuminate the phosphors. Here, an  
8     example of a low voltage is a few kilovolts (kV). Although it is possible to increase the drive  
9     voltage so that the electrons are able to penetrate the metal films and illuminate the phosphors,  
10    doing so leads to wasteful increases in power consumption.

11   **[0037]**     FIG. 1 is a partial sectional view of a flat panel display device constructed as a first  
12   embodiment of the present invention. In the first embodiment, a field emission display is used as  
13   the flat panel display of the device. It should be noted however, that the present invention is not  
14   limited to only this type of flat panel display device.

15   **[0038]**     As shown in the drawing, the field emission display (FED) includes a first substrate (or  
16   cathode substrate) 2 having predetermined dimensions, and a second substrate (or anode substrate)  
17   4 having predetermined dimensions and being provided substantially in parallel to the first  
18   substrate 2 with a predetermined gap therebetween. First and second substrates 2 and 4 are

1 connected in this state to form an exterior of the field emission display, and the air between the  
2 facing surface 2a of first substrate 2 and the facing surface 4a of second substrate 4 is evacuated  
3 to thereby form a vacuum assembly 6.

4 **[0039]** An electron emission assembly is formed on the first substrate 2. An illumination  
5 assembly is formed on the second substrate 4. The illumination assembly exhibits predetermined  
6 images by being illuminated by electrons emitted from the electron emission assembly. These  
7 structures will be described in more detail below.

8 **[0040]** With respect to the electron emission assembly, cathode electrodes 8 are formed on the  
9 facing surface 2a of first substrate 2. An insulation layer 10 is formed over and between cathode  
10 electrodes 8, and gate electrodes 12 are formed on the insulation layer 10. Holes 10a and 12a are  
11 formed respectively in insulation layer 10 and between gate electrodes 12, and electron emission  
12 sources 14 are placed in holes 10a that have been formed in insulation layer 10 and in holes 12a  
13 that have been formed between gate electrodes 12, so that electron emission sources 14 are  
14 positioned on the surface of cathode electrodes 8 opposite from cathode substrate 2.

15 **[0041]** Cathode electrodes 8 are formed on the facing surface 2a of first substrate 2 in a  
16 predetermined pattern (for example, a striped pattern of spaced-apart rows), aligned along a first  
17 direction, and with predetermined gaps between the edges of neighboring cathode electrodes 8.  
18 Insulation layer 10 is formed over an entire surface of the first substrate 2, covering cathode  
19 electrodes 8. Further, gate electrodes 12 are formed on insulation layer 10 in a predetermined

1 pattern (for example, a striped pattern), along a second direction, which may be perpendicular to  
2 the first direction, and with predetermined gaps between the stripes of gate electrodes 12. Holes  
3 10a and 12a are formed respectively in insulation layer 10 and between gate electrodes 12 as  
4 described above. Holes 10a and 12a are formed at corresponding concurrent locations.

5 **[0042]** Electron emission sources 14 are formed within holes 10a and 12a and make electrical  
6 contact with cathode electrodes 8 as described above. Electron emission sources 14 are formed  
7 in a flat configuration and made of a carbon-based material such as carbon nanotubes, fullerenes,  
8 diamond-like carbon (DLC), or graphite, or a mixture of two or more of these carbon-based  
9 materials.

10 **[0043]** Fullerenes are large carbon-cage molecules. The most common fullerene is  $C_{60}$ . Three  
11 other fullerenes, namely  $C_{70}$ ,  $C_{76}$ , and  $C_{84}$ , for instance, may be used in the formation of electron  
12 emission sources 14.

13 **[0044]** In the first preferred embodiment of the present invention, carbon nanotubes are used for  
14 electron emission sources 14. The present invention is not limited however, to these materials and  
15 to this configuration for electron emission sources 14. By way of example, it is possible to use a  
16 metal material such as molybdenum, and it is possible to construct electron emission sources 14  
17 with a circular rather than with an orthogonal or with a rectangular shape.

1     **[0045]**     With this configuration of the electron emission assembly, when external voltages are  
2     applied to cathode electrodes 8 and gate electrodes 12, electrons are emitted from electron  
3     emission sources 14 by electric fields formed between cathode electrodes 8 and gate electrodes 12.

4     **[0046]**     In the construction of the illumination assembly, anode electrodes 16 are formed on  
5     surface 4a of second substrate 4 opposing the facing surface 2a of first substrate 2. Also, R, G, and  
6     B phosphor layers 18 are formed over anode electrodes 16, and conductive layers 20 are formed  
7     on the phosphor layers 18. Anode electrodes 16 are formed of a transparent material such as  
8     indium tin oxide (ITO), and are provided in a space-apart striped pattern along the same direction  
9     as cathode electrodes 8 and are substantially aligned to correspond to the positions of cathode  
10    electrodes 8.

11    **[0047]**     Phosphor layers 18 are formed on anode electrodes 16 using a manufacturing method  
12    such as electrophoresis, that is, by the migration of charged molecules in an electrical field.

13    **[0048]**     Also, conductive layers 20 are formed on outer surfaces of the phosphor layers 18.  
14    Conductive layers 20 induce conduction paths between phosphor particles of phosphor layers 18  
15    to prevent the easy accumulation of electric charges on phosphor layers 18 during operation of the  
16    field emission display. Conductive layers 20 may be made of a carbon-based material in the  
17    practice of the present invention. For example, with reference to FIG. 2, conductive layers 20 may  
18    be formed of carbon nanotubes that adhere to the exposed surfaces of the phosphors of molecules

1 phosphor layers 18. FIG. 2 is a partial sectional view of anode substrate 4 for the flat panel display  
2 of FIG. 1, constructed in accordance with the principles of the present invention.

3 **[0049]** Conductive layers 20 may be manufactured using electrophoresis. The technique for the  
4 manufacture of the conductive layers 20 will now be described.

5 **[0050]** Referring now to FIG. 3, a schematic view used to describe a method for manufacturing  
6 a conductive layer according to an embodiment of the present invention, first, following the  
7 formation of anode electrodes 16 and phosphor layers 18 on the facing surface 4a of the second,  
8 or anode, substrate 4 as described above, anode substrate 4 is placed in a tank 30 filled with a  
9 solution 31 that contains carbon nanotubes. Solution 31 is an organic solvent or pure water  
10 containing metal salt and a dispersion agent. Also, solution 31 is preferably placed in another tank  
11 through which ultrasonic waves are passed for a predetermined amount of time in order that the  
12 carbon nanotubes do not become purified and the purified carbon nanotubes are dispersed.

13 **[0051]** Anode substrate 4 is submerged in tank 30 below the surface of solution 31, at a  
14 predetermined distance from an electrode plate 34 that is also positioned within the tank 30. An  
15 external power source such as a battery 32 is connected between electrode 34 and cathode  
16 electrodes 16, which are already formed on anode substrate 4. In this state, a predetermined bias  
17 voltage is established between electrode plate 34 and a direct current is passed through electrode  
18 plate 34 and anode electrodes 16 for a period of between one second and a few minutes. As a

1 result, these carbon nanotubes which are dispersed in solution 31 move toward anode substrate 4  
2 and eventually adhere to the exposed surfaces of the phosphor particles that form phosphor layers  
3 18. When this process is completed, anode substrate 4 is removed from tank 30, cleaned with an  
4 organic solvent or with pure water, then dried, thereby completing manufacture of the conductive  
5 layers 20.

6 **[0052]** With respect to the carbon nanotubes dispersed in solution 31 becoming purified during  
7 this process, it is preferable that the carbon nanotubes have a length of approximately 5  
8 micrometers ( $\mu\text{m}$ ) or less. Also, since the presence of the dispersent included in solution 31 may  
9 actually induce cohesion of the carbon nanotube particles when the carbon nanotube particles are  
10 first dispersed in solution 31, it is preferable that the dispersent be either diluted or be omitted  
11 from the process.

12 **[0053]** First and second substrates 2, 4 having respectively formed thereon the electron emission  
13 assembly and the illumination assembly, as described above, are interconnected with a  
14 predetermined gap therebetween and with the electron emission assembly and the illumination  
15 assembly facing one another. A sealant (not shown) is provided around a circumference of  
16 surfaces of the first and second substrates 2 and 4 facing each other to interconnect these elements  
17 as an integral and unitary single structural monolithic unit. Before making this structural  
18 connection of the first and second substrates 2 and 4, spacers 22 are provided therebetween at  
19 non-pixel regions. The spacers 22 maintain the predetermined gap between the first and second



substrates 2 and 4.

**[0054]** FIG. 4 is a graph used to compare a first display, corresponding to the first embodiment of the present invention, with a second display serving as a comparative example. The field emission display structured as in the present invention described above removes the accumulation of electric charge that occurs on the phosphor layers 18 during operation, and attains improved brightness characteristics over comparable devices that do not include conductive layers 20. This is shown in the graph of FIG. 4.

**[0055]** With reference to FIG. 4, the field emission display of the first embodiment of the present invention exhibits a higher current density over the comparative exemplary device at the same electric field strengths, except at the highest levels of electric field strength where it is undesirable to operate a display device. This indicates that in the field emission display of the present invention, when the electrons emitted from electron emission sources 14 are directed toward phosphor layers 18 and strike the same, the electric charge on the surfaces of the phosphor layers 18 is reduced by flowing through electrically conductive layers 20 to the outside of the vacuum assembly 6. Also, such a result is an indication of how the illumination of phosphor layers 18 is increased by the landing of electrons. In fact, through experimentation, the inventors determined that an approximately 7% greater brightness is realized in the first preferred embodiment of the present invention when compared to the comparative exemplar.

1   **[0056]**   A more detailed description of the formation of conductive layers 20 on the second  
2   substrate will be described. First, following the formation of phosphor layers 18 on anode  
3   substrate 4 by using electrophoresis, carbon nanotubes and metallic salt are dispersed in pure water  
4   to prepare the solution. The amount of the carbon nanotubes can be approximately 0.5 grams (g),  
5   for example, and the metallic salt can be one or more of the salts of magnesium (Mg), for example.

6   **[0057]**   To improve the degree of dispersion of the carbon nanotubes, the solution may undergo  
7   an ultrasonic wave process for roughly sixty minutes. The second substrate 4 is then immersed  
8   in the solution, and a bias voltage is applied to the electrode plate 34 and the anode electrodes 16  
9   for 20 seconds. A bias voltage of approximately 20 volts (V) is applied through power source 32.  
10   As a result, the carbon nanotubes dispersed in the solution adhere to phosphor layers 18. Anode  
11   substrate 4 is then removed from the solution, cleaned for approximately ten seconds, and dried  
12   for about sixty minutes at a temperature of approximately 100° Celsius (°C) to thereby complete  
13   the formation of conductive layers 20. The field emission display of the comparative exemplar  
14   is configured identically as the first example of the present invention, except that the comparative  
15   exemplar does not include the formation of conductive layers.

16   **[0058]**   FIG. 5 is a partial sectional view of an anode substrate constructed as a modification of  
17   the first embodiment of the present invention. FIG. 6 is a partial sectional view illustrating an  
18   anode substrate constructed as another modification of the first embodiment of the present  
19   invention.

1   **[0059]** With reference to FIGS. 5 and 6, the field emission display constructed according to the  
2   first embodiment of the present invention may also include black matrix layers 24 formed on the  
3   second substrate 4 interposed between phosphor layers 18 and anode electrodes 16. Black matrix  
4   layers 24 are formed of electrically conductive materials and serve to improve the contrast of the  
5   field emission display. The black matrix layers 24 may be mounted between without physically  
6   contacting the anode electrodes 16 as shown in FIG. 5, where interstices or gaps 24a occur between  
7   the sidewalls of neighboring anode electrodes 16 and black matrix layers 24, or alternatively, black  
8   matrix layers 24 may be mounted between and physically contact anode electrodes 16 as shown  
9   in FIG. 6. In the latter case, the black matrix layers 24 also physically contact the conductive  
10   layers 20.

11   **[0060]** In the case where the black matrix layers 24 are formed without making contact with the  
12   anode electrodes, such as is illustrated by FIG. 5, it is possible to drive the display using an anode  
13   drive method. Further, in addition to electrophoresis, the phosphor layers 18 may be formed  
14   through various other methods such as a slurry method or a screen printing method.

15   **[0061]** In the case where the black matrix layers 24 are formed in physical contact with anode  
16   electrodes 16, such as is illustrated by FIG. 5, there are limitations given with respect to the  
17   forming of the phosphor layers 18 (for example, it is not possible to use electrophoresis to form  
18   phosphor layers 18). However, such a configuration allows for the current-sending effects of black  
19   matrix layers 24 to be maximized.

1     **[0062]**   In the flat panel display device of the present invention, as a result of the improvements  
2     made in the conductive layers 20 formed on the phosphor layers 18, when the electrons emitted  
3     from the electron emission assembly strike the phosphor layers 18, electric charges do not  
4     accumulate on the surfaces of phosphor layers 18 and instead are induced to travel the outside of  
5     the video display device. This improves overall brightness of the visual images broadcast by the  
6     display device to its audience while concomitantly increasing the lifespan of phosphor layers 18.

7     **[0063]**   Furthermore, the electric charges accumulated on the surfaces of phosphor layers 18 may  
8     also be effectively removed, even under low voltage driving conditions. Therefore, arcing caused  
9     by the accumulated electric charges is substantially prevented.

10    **[0064]**   Also, in the case where conductive layers 20 are formed of carbon nanotubes, the carbon  
11    nanotubes adsorb impure gases within vacuum assembly 6. For example, the adsorbed impure  
12    gases may include oxygen gas (O<sub>2</sub>), carbon monoxide gas (CO), and nitrogen gas (N<sub>2</sub>). This  
13    improves the state of the vacuum within vacuum assembly 6.

14    **[0065]**   In addition, since the relatively easy electrophoresis process may be used to produce  
15    conductive layers 20, the overall fabrication and manufacture of the field emission display is  
16    significantly simplified.

17    **[0066]**   Although preferred embodiments of the present invention have been described in detail

1 herein above, it should be clearly understood that many variations and modifications of the basic  
2 principles and the inventive concepts taught herein which may appear to those skilled in the  
3 applicable art, will still fall within the spirit and scope of the present invention, as defined in the  
4 appended claims.

5 **[0067]** Referring now to FIG. 7 as an example, elements that form the electron emission  
6 assembly, may be formed in a different order and in an alternative configuration than that  
7 described above. That is, gate electrodes 12 may be first formed on cathode substrate 2, then an  
8 insulation layer 10 may be formed on the gate electrodes 12. FIG. 7 is a partial sectional view of  
9 a flat panel display which illustrates a second embodiment of the present invention.

10 **[0068]** Cathode electrodes 8 are then provided on insulation layer 10 and electron emission  
11 sources 14 are formed on cathode electrodes 8. Gate electrodes 12 and the cathode electrodes 8  
12 may be formed identically to the way they are formed in the first preferred embodiment of the  
13 present invention. That is, the gate electrodes 12 and the cathode electrodes 8 are formed in a  
14 striped patterns that overlay and perpendicularly intersecting one another. The electron emission  
15 sources 14 may be made from the same materials as may be used in the fabrication of the first  
16 preferred embodiment.

17 **[0069]** Turning now to FIG. 8, unlike the striped pattern used in the first embodiment, it is  
18 possible to form a single anode electrode 16 over an entire surface of a second substrate 4 as

1 shown by FIG. 8. In this embodiment, phosphor layers 18, conductive layers 20, and black matrix  
2 layers (not shown) may be formed identically as in the first embodiment of the present invention.

3 FIG. 8 is a partial sectional view of a flat panel display which illustrates a third embodiment of the  
4 present invention. As shown in FIG. 8, the single anode electrode 16 covers the entire surface of  
5 second substrate 4, or at least covers a large percentage of the surface of second substrate 4. For  
6 example, as shown in FIG. 8, anode electrode 16 can be said to be a single large unit 16 that covers  
7 over approximately 80% of the surface of the second, or anode, substrate 4 facing the first, or  
8 cathode, substrate 2.

9 **[0070]** As shown in FIG. 1, the major surface 2a of the first, or cathode, substrate 2 that faces  
10 anode substrate 4 can be referred to as the facing surface 2a of cathode substrate 2, as the inside  
11 surface 2a of cathode substrate 2, or as the first surface 2a of cathode substrate 2. The surface  
12 major 4a of the second substrate 4 that faces the cathode substrate 2 can be referred to as the facing  
13 surface 4a of the second, or anode, substrate 4, as the inside surface 4a of anode substrate 4, or as  
14 the first surface 4a of anode substrate 4.

15 **[0071]** While the present invention has been illustrated by the description of embodiments  
16 thereof, and while the embodiments have been described in considerable detail, it is not the  
17 intention of the applicant to restrict or in any way limit the scope of the appended claims to such  
18 detail. Additional advantages and modifications will readily appear to those skilled in the art.  
19 Therefore, the invention in its broader aspects is not limited to the specific details, representative

1 apparatus and method, and illustrative examples shown and described. Accordingly, departures  
2 may be made from such details without departing from the spirit and scope of the applicant's  
3 general inventive concept.